Nature Conservation 51: 1–12 (2023)
doi: 10.3897/natureconservation.51.95690
https://natureconservation.pensoft.net

SHORT COMMUNICATION

A peer-reviewed open-access journal
Nature Conservation
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# Reencounter with the past: occurrence of sei whale (*Balaenoptera borealis*) in an old hunting area in the south-eastern Pacific Ocean

Andrea Cisterna-Concha[1,2], Camila Calderón-Quirgas[1,3], Fernanda Silva-Andrades[4], Richard Muñoz[2,5], Heraldo V. Norambuena[6,7]

**1** *Centro de Estudios de Mastozoología Marina, Concepción, Chile* **2** *Programa de Doctorado en Oceanografía, Departamento de Oceanografía, Facultad de Ciencias Naturales y Oceanográficas, Universidad de Concepción, Concepción, Chile* **3** *Programa de Magíster en Ciencias mención en Oceanografía, Departamento de Oceanografía, Facultad de Ciencias Naturales y Oceanográficas, Universidad de Concepción, Concepción, Chile* **4** *Turismo Chome Aventura, Biobío, Caleta Chome, Hualpén, Chile* **5** *Departamento de Ecología, Facultad de Ciencias, Universidad Católica de la Santísima Concepción, Concepción, Chile* **6** *Centro Bahía Lomas, Facultad de Ciencias, Universidad Santo Tomás, Concepción, Chile* **7** *Centro de Estudios Agrarios y Ambientales, Valdivia, Chile*

**Corresponding author:** Heraldo V. Norambuena (hnorambuena@santotomas.cl)

**Academic editor:** A. Thessen | Received 27 September 2022 | Accepted 11 January 2023 | Published 26 January 2023

*https://zoobank.org/AC870C30-7C73-4D1A-816C-C42AABE7C7B1*

**Citation:** Cisterna-Concha A, Calderón-Quirgas C, Silva-Andrades F, Muñoz R, Norambuena HV (2023) Reencounter with the past: occurrence of sei whale (*Balaenoptera borealis*) in an old hunting area in the south-eastern Pacific Ocean. Nature Conservation 51: 1–12. https://doi.org/10.3897/natureconservation.51.95690

## Abstract

The sei whale (*Balaenoptera borealis*) was intensively exploited throughout its range, with about 110.000 individuals hunted by pelagic fleets in Antarctic waters between 1960 and 1970. In addition, basic information on its distribution, migratory routes, and feeding grounds in the southeastern Pacific, has been poorly documented. In the case of Chile, recent information consists mainly of accidental records. This research presents the first sei whale photo-identification catalog for south-central Chile. From November 2019 to January 2020, 88 individuals were recorded from land-based and boat surveys at Caleta Chome. Of these, 12 individuals were photo-identified through scars or distinctive notches in the dorsal fins. The peak of sightings occurred during December 2019; two individuals were sighted on more than one occasion.

## Keywords

*Balaenoptera borealis*, Caleta Chome, Chile, Sei whale, South-eastern Pacific

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## Introduction

The sei whale (*Balaenoptera borealis*) is an endangered mysticete (Cooke 2018) and the third largest whale after the blue whale (*Balaenoptera musculus*) and the fin whale (*Balaenoptera physalus*; Horwood 2018). This species presents a cosmopolitan distribution and pelagic with temperatures below 20 °C (Omura and Nemoto 1955; Gambell 1968, 1985). It migrates to the southern hemisphere during summer, from areas near the subtropical convergence where it reproduces, to areas near the Antarctic convergence (50°S–60°S) for feeding (Horwood 1987; Reeves et al. 1998; Rice 1998). Feeding zones are unpredictable, with a sudden influx into an area, followed by their disappearance and subsequent absence for years (Gambell 1985; Reeves et al. 2002; Jefferson et al. 2008). During the summer there are high concentrations of sei whales between 40° and 50°S with adult individuals reaching polar waters while juveniles or sub-adults stay north of the Antarctic convergence (Lockyer 1977; Acevedo et al. 2017). Six populations have been assumed for the southern hemisphere for management purposes; however, the scarce evidence has failed to identify separate populations within ocean basins (Kanda et al. 2006; Horwood 2018).

The International Whaling Commission estimated that by the 1940s the population declined from 191.000 to 37.000 individuals after the cessation of commercial catches in 1983 (Gambell 1985). Although the sei whale was not a target species for hunting until the early 1960s (Acevedo et al. 2017; Español-Jiménez et al. 2019) the decrease in the most profitable whales (*B. musculus*, *B. physalus*, *Megaptera novaeangliae* and *Eubalaena australis*) led to an increase in the hunting effort for this species. In South America, this species was heavily exploited throughout its range (Zerbini et al. 1997; Aguayo-Lobo et al. 1998a) where about 110.000 individuals were hunted by pelagic fleets in Antarctic waters between 1960 and 1970 (Horwood 2018). In Chile, it was the third most hunted whale species between 1929 and 1979 with at least 1,664 individuals captured (Aguayo 1974); however, due to the difficulty of differentiating from Bryde's whale (*Balaenoptera edeni*) during this whaling period, its hunting numbers are probably overestimated since many Bryde's whales would have been reported as sei whales (Valdivia et al. 1981; Gallardo et al. 1983; Aguayo-Lobo et al. 1998a). There were about 25 years (between 1974 and 1999) in which there was no research on sei whales, and the few studies that were conducted during this period did not consider the sei whale as an object of study (Gallardo and Pastene 1983; Gallardo et al. 1983; Guerra-Correa et al. 1987; Aguayo-Lobo et al. 1998b). Since the moratorium on whaling established in 1983, there has been a considerable reduction in sei whale research (Reeves et al. 2002); currently this species is one of the least known baleen whales in the world (Prieto et al. 2012; Acevedo et al. 2017; Horwood 2018).

Caleta Chome was founded by the Macaya Hnos. whaling industry on 1948 (Quiroz and Carreño 2019). By 1954, the sei whale was already within the productivity of the whaling plant in Caleta Chome and was the first documented record of sei whales for this region. The sei whale catch data for this area were for a long time under the name "S + B", since they considered the bryde (B) and sei (S) whales together due to their similarities, therefore there are no clear records of the number of individuals of sei

whales caught in this area (Pastene 1982). In Caleta Chome, between 1951 and 1983, active whaling was carried out by the Trinidad Whaler owned by the Macaya Family (Quiroz and Carreño 2019). Given that the sei whale is endangered, studies of its populations are crucial to support its conservation. This study presents the first sei whale photo-identification catalog in south-central Chile and information on sightings.

## Materials and methods

### Study area

The sightings were in Caleta Chome in the Biobío region of Chile (36°40'S, 73°15'W; Fig. 1). Waters rich in nutrients from the Humboldt Current fertilize the coasts of this region in the spring and summer season when the winds are favorable to coastal upwelling (Sobarzo et al. 2007; Simpkins 2018), generating an increase in primary productivity and higher trophic levels (Thiel et al. 2007; Escribano et al. 2012; Anabalón et al. 2016). South of Caleta Chome, the freshwater discharge from the Biobío River provides nutrients, organic matter, and terrigenous particles to the adjacent coastal area, so positively influencing phytoplankton biomass and primary production (Masotti et al. 2018). Bathymetric accidents such as the Biobío canyon (Sobarzo et al. 2016) and an irregular coastline (Figueroa and Moffat 2000) are essential factors in the coastal dynamics of the area.

### Sighting and data base

The sighting records were collected between November 2019 and January 2020 two days per week for a total of 25 days (41 hours and 15 min) of monitoring. The surveys (search of whales) were conducted during the morning between 08:00–12:00 AM (14 surveys) and afternoon between 06:00–09:00 PM (11 surveys). The sightings were made from a) land from a hill of 50–55 m of height using 10×42 binoculars and spotting scopes 15–45 × 65 (16 surveys); and b) aboard the boat El Felipe I (7.8 m in length) that periodically sails in Caleta Chome (9 surveys). The number of observers varied from 2 to 4. From the boat, the sightings were at a distance of no greater than 20 m and the identification of the species was carried out with photographic records using a Canon EOS77D camera with 100–400 mm zoom lens, and Canon SX530 semi-professional camera. The morphology of the dorsal fin, characterized by a prominent falcate fin that rises at a steep angle from the rear and central ridge along the head, allowed species identification (Acevedo et al. 2017). The individuals were individualized based on photographs by identifying the distinctive scars, notches, or holes in the dorsal fin (Würsig and Jefferson 1990). Only images of medium to high quality (> 4608 × 3456 pixels) that allowed to highlight their distinctive characteristics were used.

Daily Sea Surface Temperature (SST) between November 2019 and January 2020 data were obtained from Multi-Scale Ultra High Resolution (MUR, https://podaac.jpl.nasa.gov/dataset/MUR-JPL-L4-GLOB-v4.1) with a spatial resolution of 1 km$^2$. The SST for each sei whale sighting at sea was obtained from the near pixel to the sighting coordinate.

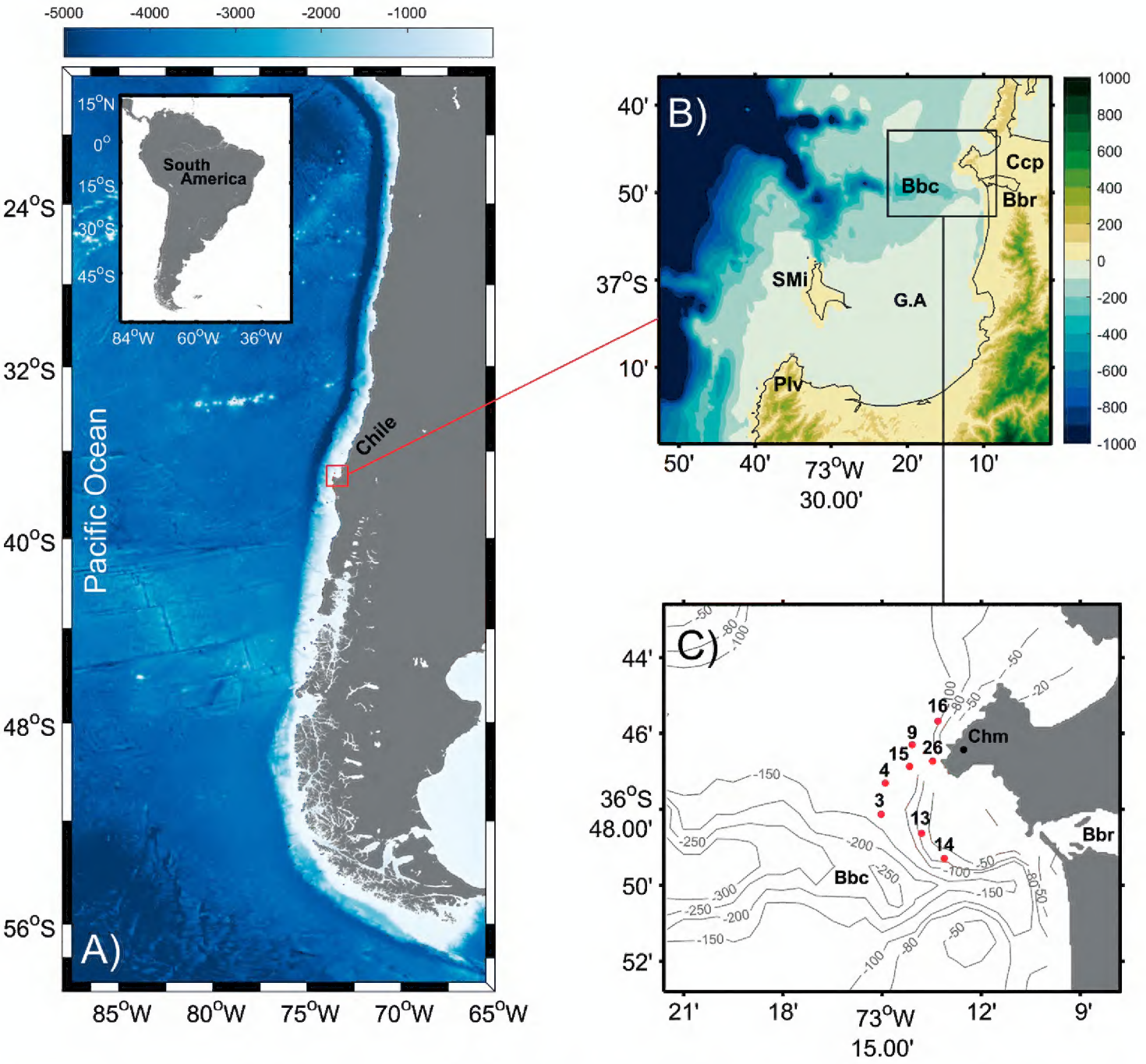


**Figure 1.** Study area **B** G.A: Arauco gulf, SMI: Santa Maria Island, Llv: Punta Lavapié, Bbc: Biobío canyon, Bbr: Biobío River and Ccp: Concepción **C** Localization of sightings in Caleta Chome. The red point shows the position of the sightings in the sea. The associated sampling number is indicated on each point (see Table 1). The black point shows the position of Caleta Chome, where sightings from land were made. The color palette in **A** and **C** panel shows the depth in meters. The bathymetric information for the area was obtained from the General Bathymetric Chart of the Ocean (GEBCO, GEBCO – The General Bathymetric Chart of the Oceans).

## Data analysis

To have a better visualization of the results of the sightings, a detection index (Di) was established which was calculated based on the sum of the sightings made during intervals of 10 days (i.e., maximum interval between monitoring) and the effective sampling effort within that interval of days:

$$Di = \text{sightings during 10 days} / \text{sampling effort for 10 days}$$

## Results

Between November 3 and January 18, we made 88 sei whale sightings. The number of sightings varied from November to January, registering a peak of sightings on December 11 and 20 (Fig. 2). We identified 17 groups of sei whale of 2 to 9 individuals (median = 4); most of these groups were registered during the month of December (10 groups). The SST range from 12.7 °C to 15.1 °C during the sightings, and the estimated depths of the sightings range from 16 to 137 m. On the other hand, sei whale sightings ware made at mean distance of 3.6 km from the coast. We highlight one event, where the distance was around 0.1 km. (Table 1).

Twelve individuals were photo-identified through distinctive scars or notches on the dorsal fins (Fig. 3), 83% of the individuals have some notch and one of them has a broken fin (# 002) and another two had lacerations (# 007 and # 009). Most individuals (see photographic sequence from # 009 to # 012 in Fig. 3) were photographed in December 2019. Two individuals (# 003 and # 009) were sighted more than one day in the area, individual # 003 was sighted 7 days after the first sighting and individual # 009 on the seventh and tenth day after the first sighting. The presence of a mother with a calf was registered for 5 different days.

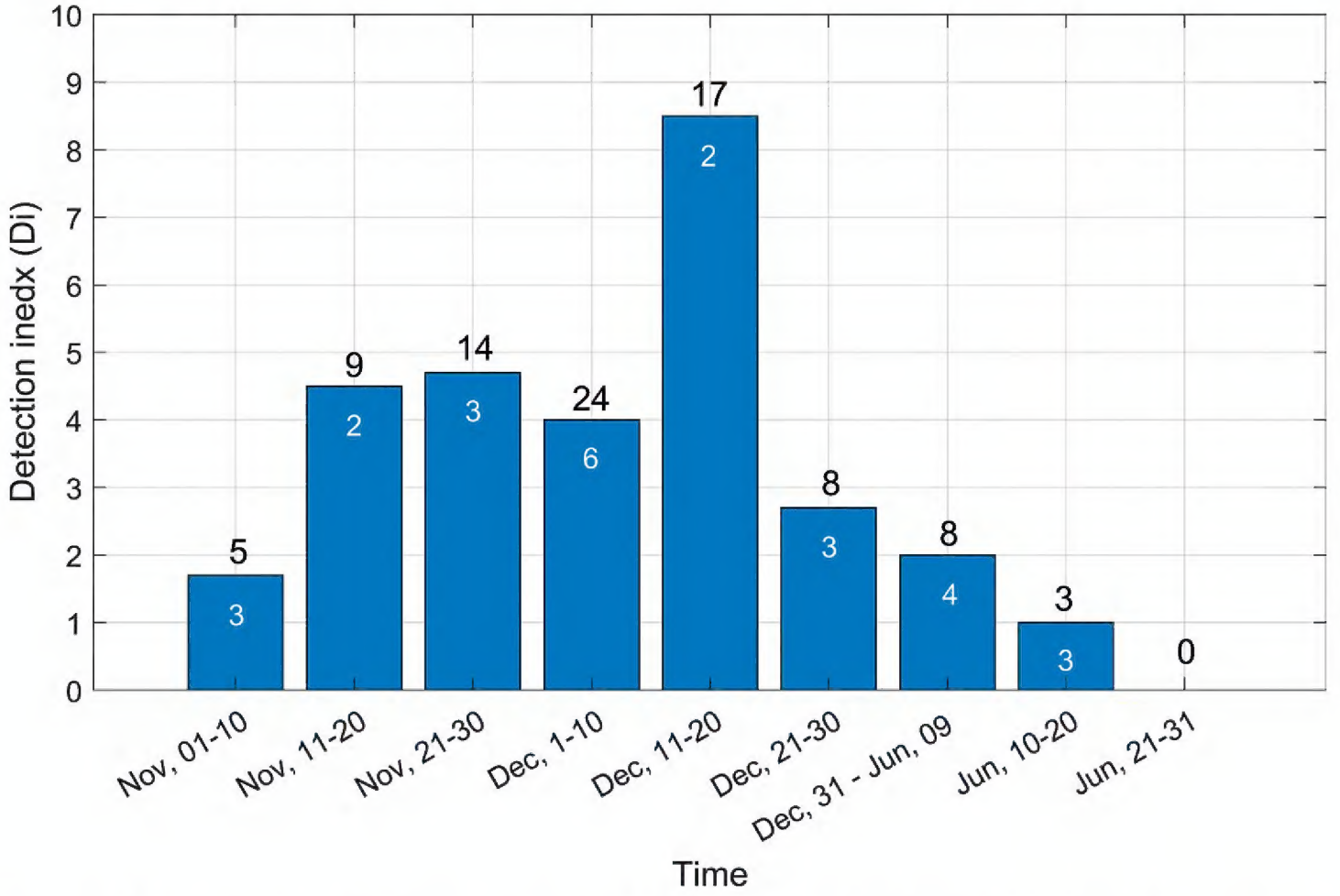


**Figure 2.** Frequency in the detection index of the *Balaenoptera borealis* sighted during November and December 2019 and January 2020. The detection rate was calculated based on the effective sightings per day for 10 days standardized by the sampling effort. The numbers above and within each bar indicate the number of total sightings and the sampling effort in each date range, respectively.

**Table 1.** Summary of sightings of sei whales (*Balaenoptera borealis*) in Caleta Chome during the seasons from November 2019 to January 2020. Note: the number of individuals with * represents those sightings in which mothers with young were recorded.

| No. | Date (d/m/y) | GPS Coordinates (Latitude, Longitude) | Number of individuals | Sighting place | Distance from shore (km) | SST (°C) | Depth (m) |
|---|---|---|---|---|---|---|---|
| 1 | 03-11-2019 | – | 1 | Coast | – | – | – |
| 2 | 06-11-2019 | – | 3* | Coast | – | – | – |
| 3 | 09-11-2019 | 36°48'10.64"S, 73°13'45.58"W | 1 | Boat | 4.4 | 12.9 | 113 |
| 4 | 17-11-2019 | 36°47'18.55"S, 73°14'54.26"W | 4* | Boat | 5.6 | 15.1 | 137 |
| 5 | 18-11-2019 | – | 5 | Coast | – | – | – |
| 6 | 28-11-2019 | – | 6 | Coast | – | – | – |
| 7 | 29-11-2019 | – | 4* | Coast | – | – | – |
| 8 | 30-11-2019 | – | 4 | Coast | – | – | – |
| 9 | 01-12-2019 | 36°46'17.00"S, 73°13'40.75"W | 6 | Boat | 1.6 | 13.5 | 122 |
| 10 | 02-12-2019 | – | 1 | Coast | – | – | – |
| 11 | 05-12-2019 | – | 3 | Coast | – | – | – |
| 12 | 06-12-2019 | – | 2 | Coast | – | – | – |
| 13 | 07-12-2019 | 36°48'35.88"S, 73°13'30.39"W | 8 | Boat | 4.6 | 12.7 | 103 |
| 14 | 08-12-2019 | 36°49'17.70"S, 73°13'7.15"W | 4 | Boat | 5.4 | 12.8 | 122 |
| 15 | 13-12-2019 | 36°46'44.59"S, 73°13'41.02"W | 9* | Boat | 1.1 | 13.3 | 105 |
| 16 | 14-12-2019 | 36°45'40.66"S, 73°13'18.85"W | 8 | Boat | 2.4 | 12.9 | 116 |
| 17 | 22-12-2019 | – | 3 | Coast | – | – | – |
| 18 | 23-12-2019 | – | 1 | Coast | – | – | – |
| 19 | 30-12-2019 | – | 4* | Coast | – | – | – |
| 20 | 31-12-2019 | – | 4 | Coast | – | – | – |
| 21 | 06-01-2020 | – | 1 | Coast | – | – | – |
| 22 | 08-01-2020 | – | 1 | Coast | – | – | – |
| 23 | 09-01-2020 | – | 2 | Coast | – | – | – |
| 24 | 10-01-2020 | – | 1 | Coast | – | – | – |
| 25 | 13-01-2020 | – | 1 | Coast | – | – | – |
| 26 | 18-01-2020 | 36°46'40.98"S, 73°12'54.39"W | 1 | Boat | 0.1 | 12.7 | 16 |

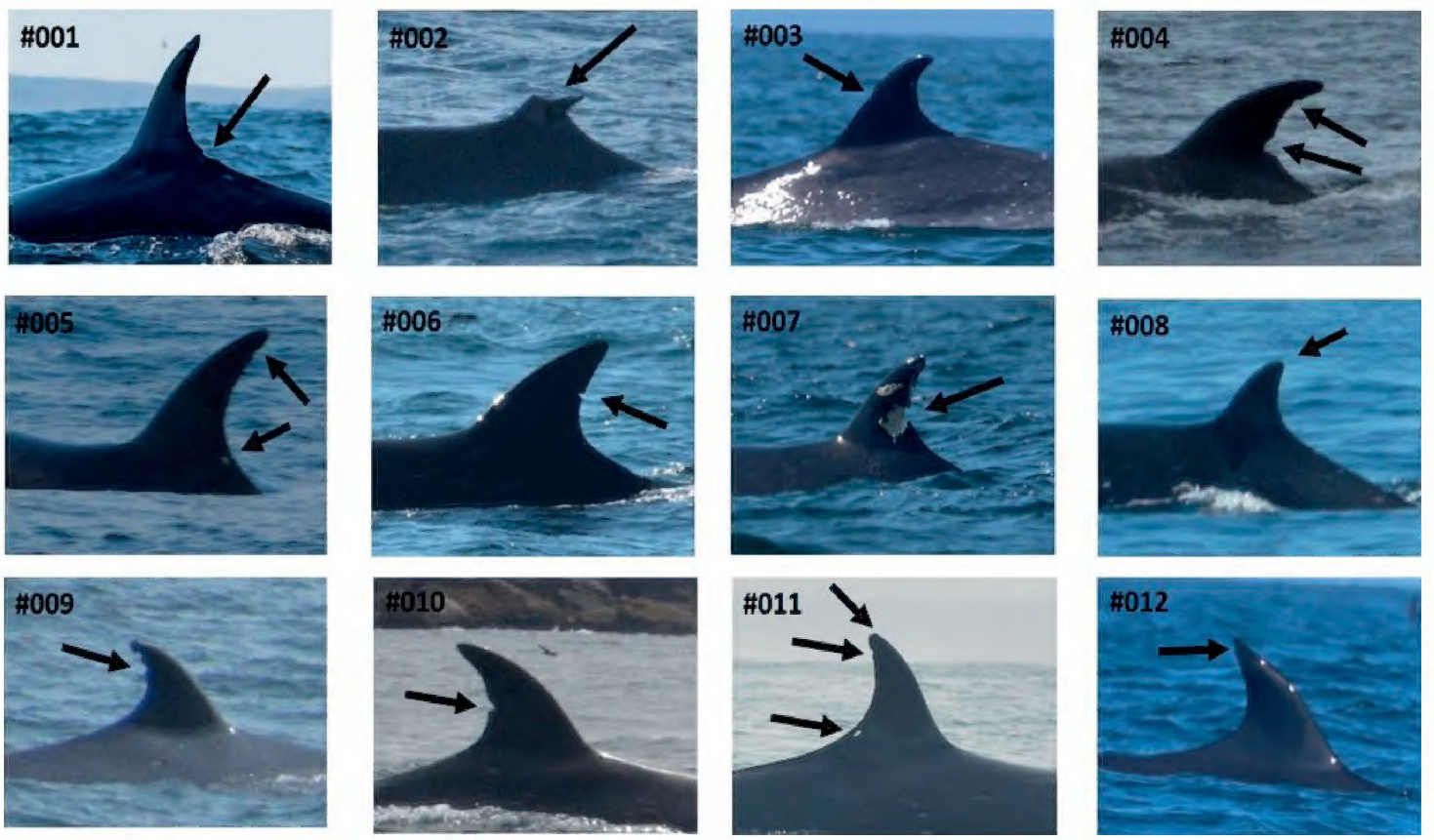


**Figure 3.** Dorsal fin photographs of 12 identified sei whales (*Balaenoptera borealis*) at Caleta Chome, during the seasons from November 2019 to January 2020.

## Discussion

With the moratorium established by the International Whaling Commission (IWC) in 1983, the cetacean records associated with hunting decreased and the only records of the sei whale for central Chile were only three reports and one scientific publication (Pastene 1982; Gallardo and Pastene 1983; Gallardo et al. 1983; Aguayo-Lobo et al. 1998a). Although there are records of sightings of this species in previous years (F. Silva obs. pers.), a high abundance of individuals was not recorded in this area and neither was the presence of mothers with young.

The sei whale is described as predominantly found in deep waters, occupying mainly pelagic habitats at distances greater than 110 km from the coast (Best and Lockyer 2002; Prieto et al. 2012); however, many of our sightings occurred near the coast at distances no greater than 6 km (see Table 1) consistent with what was observed for populations of sei whales in the South Atlantic (Weir et al. 2020). This greater abundance of sei whales near the coast and the feeding activity during the day, agree with the results obtained by Español-Jiménez et al. (2019) on the coast of the Gulf of Penas and Tres Montes. Another data to highlight is the sightings of the same individual on more than one occasion; this suggests a stay of at least 7–10 days. In addition, the presence of mothers with young during the observation season may be giving signs of safety and good environmental conditions for rearing. More than 50% of the identified individuals had scars on their fins. Among the possible natural threats that could have damaged its dorsal fin, is predation by killer whales (*Orcinus orca*) which are considered its only significant natural predator (Jefferson et al. 1991; Springer et al. 2006).

The occurrence of sei whales in the coastal upwelling system of Chile was reported by Gallardo and Pastene (1983), who associated high primary productivity with the concentration of sightings, proposing that the coasts of the Biobío region can be feeding areas for some cetaceans during their migrations. The continental shelf off Biobío is an important upwelling zone and has been described as one of the most productive areas within the Humboldt Current System (Montecino et al. 1998; Montero et al. 2007; Thiel et al. 2007; Daneri et al. 2012; Iriarte et al. 2012). Bathymetric features such as underwater canyons generate foraging areas for a variety of cetaceans, contributing to primary productivity and biodiversity (Moors-Murphy 2014). Croll et al. (2005) mention that bathymetric ruptures and the coastal upwelling process are important factors in the density of euphausiids, contributing to the formation of feeding areas. The high occurrence of individuals in Caleta Chome could be related to a migratory route close to the Biobío Canyon located to the south of the study area.

The oceanographic conditions in the distribution of this species are variable in relation to the migratory routes and the permanence in feeding and / or reproduction sites (Omura and Nemoto 1955; Gregr and Trites 2001; Sasaki et al. 2013; Murase et al. 2014). On the coasts of Chile, the presence of sei whales has been reported in areas with sea surface temperatures of 14.5 °C in spring (Clarke et al. 1978). In the Magellan Strait Acevedo et al. (2017) reported a thermal range between 5.7 and 10.9 °C. Our sightings are also within this temperature range, agreeing with the values reported for this species in other parts of the world (Sasaki et al. 2013).

Acevedo et al. (2017) reported sei whales in the Magellan Strait from November to May, with a peak of sightings (83.6%) occurring during December and January. They suggest that although there are records that support the hypothesis that whales forage in southern Chile, none of them provide information on systematic annual occurrences in these same areas. But this, in turn, can be supported by the fact that sei whales are known for their unpredictable presence in an area followed by their subsequent disappearance, as well as having a greater variation in distribution in their feeding grounds than most species of baleen whales (Tønnessen and Johnsen 1982; Horwood 1987). All these records that support the presence of the sei whale on Chilean coasts are at the same time of the year (January–May) within relatively small latitudes and, although they are not in consecutive years, there is a certain periodicity that could support the hypothesis that the sei whale forages in Chilean waters but their foraging areas change over the years (Pastene and Shimada 1999; Aguayo-Lobo et al. 2006; Guzmán 2006; Acevedo et al 2017; Español-Jiménez et al. 2019) This may be due to an underestimation of the presence of this species in Chile, since there is no systematic monitoring in all the areas that it has been recorded. In this work, the occurrence of the sei whale off the Chilean coast shows the existence of a passage zone and possible feeding area within the waters near the coast. Ecological knowledge about sei whales along the Chilean coast is scarce, therefore we highlight the importance of increasing sighting efforts around the Hualpén Peninsula Nature Sanctuary during upwelling events to understand if the presence of sei whales follows some seasonal pattern or corresponds to sporadic events.

## Acknowledgements

We thank the Turismo Chome Aventura company for the navigation services in Caleta Chome and the information provided through verbal communication of sei whale sightings and navigation routes commonly used by whales. A.C.C thanks the COPAS-coastal center, Universidad de Concepción, Chile and the Agencia Nacional de Investigación y Desarrollo de Chile (ANID).

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